# Utility Systems Integration

## Wind Farm Monitoring

National Wind Technology Center

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November 17, 2004

# Presentation Topics

- What Are the Issues
- What Does This Program Try to Achieve
- Approaches
- What We Have Learned
- What Are Still Needed
- On Going Effort for FY2005
- Industry Collaborations

# What are the Issues?

- Rapid increase of wind power in the grid and more utilities are connecting wind power in their systems
- Compared to conventional generating technologies, utilities still lack experience in operating and planning for wind; there are misconceptions about wind power behavior
- Utilities and ISOs need to know how wind power will affect the grid operations (ancillary services requirements, reserves, power quality issues, etc.)
- Real wind farm data needed for system operational studies (long-term) and for model validation (high-frequency); but the required data are often not available—either not archived or proprietary

# What Does This Program Try to Achieve?

- Collect long-term, actual output data from commercial wind farms to characterize the real behavior of wind power
- Record high-frequency voltage and current data at wind farms to analyze the transient characteristics of large wind farms
- Collect high-frequency data for wind farm dynamic model validation
- Maintain the database and make it available for industry for wind integration and impact studies while protecting sensitive business information

# Approaches

- Work with wind plant owners/operators and host utilities to record 1-second wind power data at 3 wind farms in Iowa and Minnesota
- Collaborating with ERCOT to record 1-second wind power data from 4 wind farms in Texas
- Collaborating with Western Farmers Electric Cooperative (WFEC) to record 10-minute wind power data from 1 wind farm in Oklahoma
- Collect event-triggered, 10-second V and I waveforms at sampling rate of 120 Hz from 4 Texas wind farms

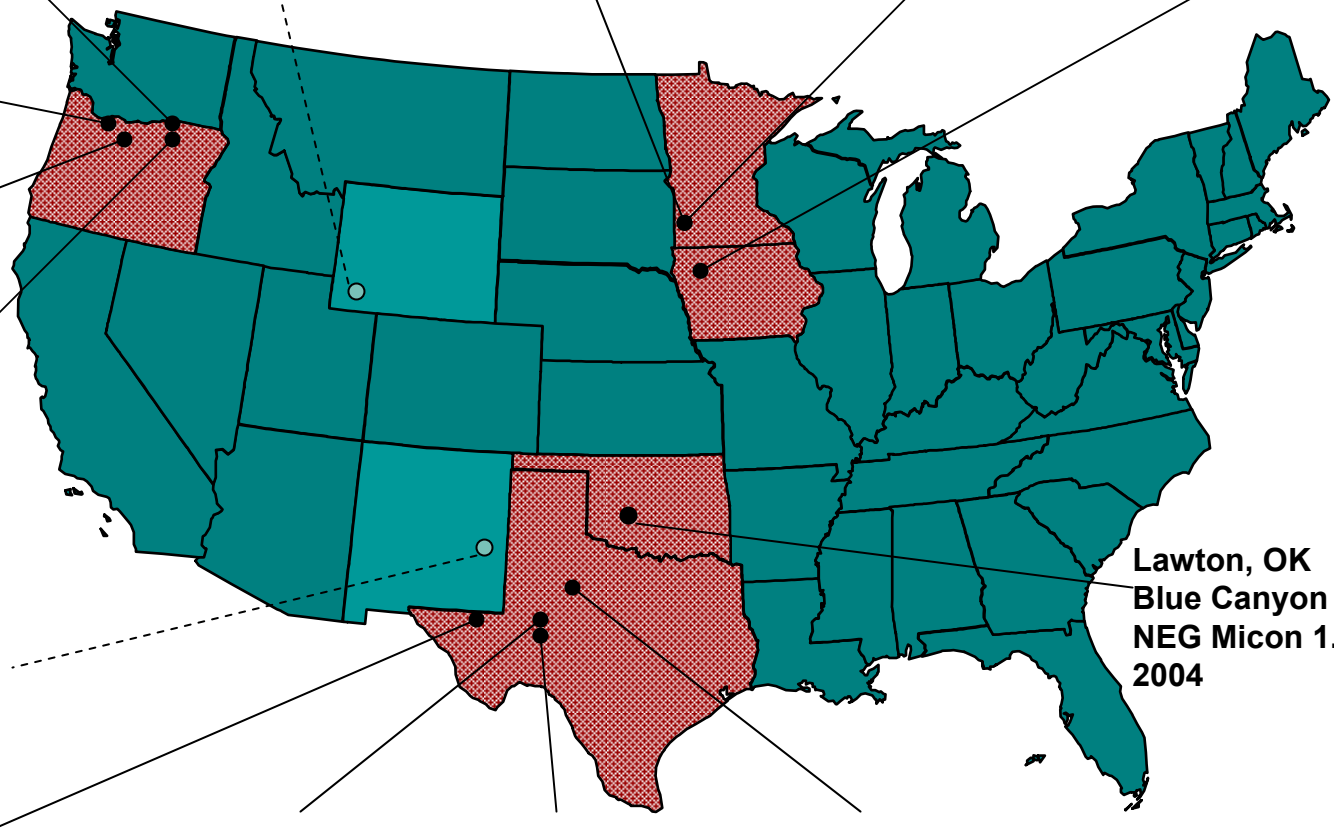
# Wind Farm Monitoring Project

(Total capacity ~940 MW)

NREL

Sandia National Laboratories

NWTC



WA-OR Border
Stateline
Vestas V47/90 MW
2002

WY Wind Energy Ctr.
Evanston, WY
Vestas V80/144 MW

Lake Benton, MN
Lake Benton II
GE Z50/104 MW
2000

Lake Benton, MN
Buffalo Ridge Sub
~ 240 MW
2001

Storm Lake, IA
Buena Vista Sub
GE Z50/113 MW
2001

Klondike, OR
GE 1.5MW/25 MW
2002

Condon, OR
Mitsubishi MWT600
25 MW
2002

Vansycle, OR
Mitsubishi MWT600
25 MW
2002

NW Wind Energy Ctr.
Taiban Mesa, NM
GE 1.5MW/204 MW

Lawton, OK
Blue Canyon
NEG Micon 1.65/74MW
2004

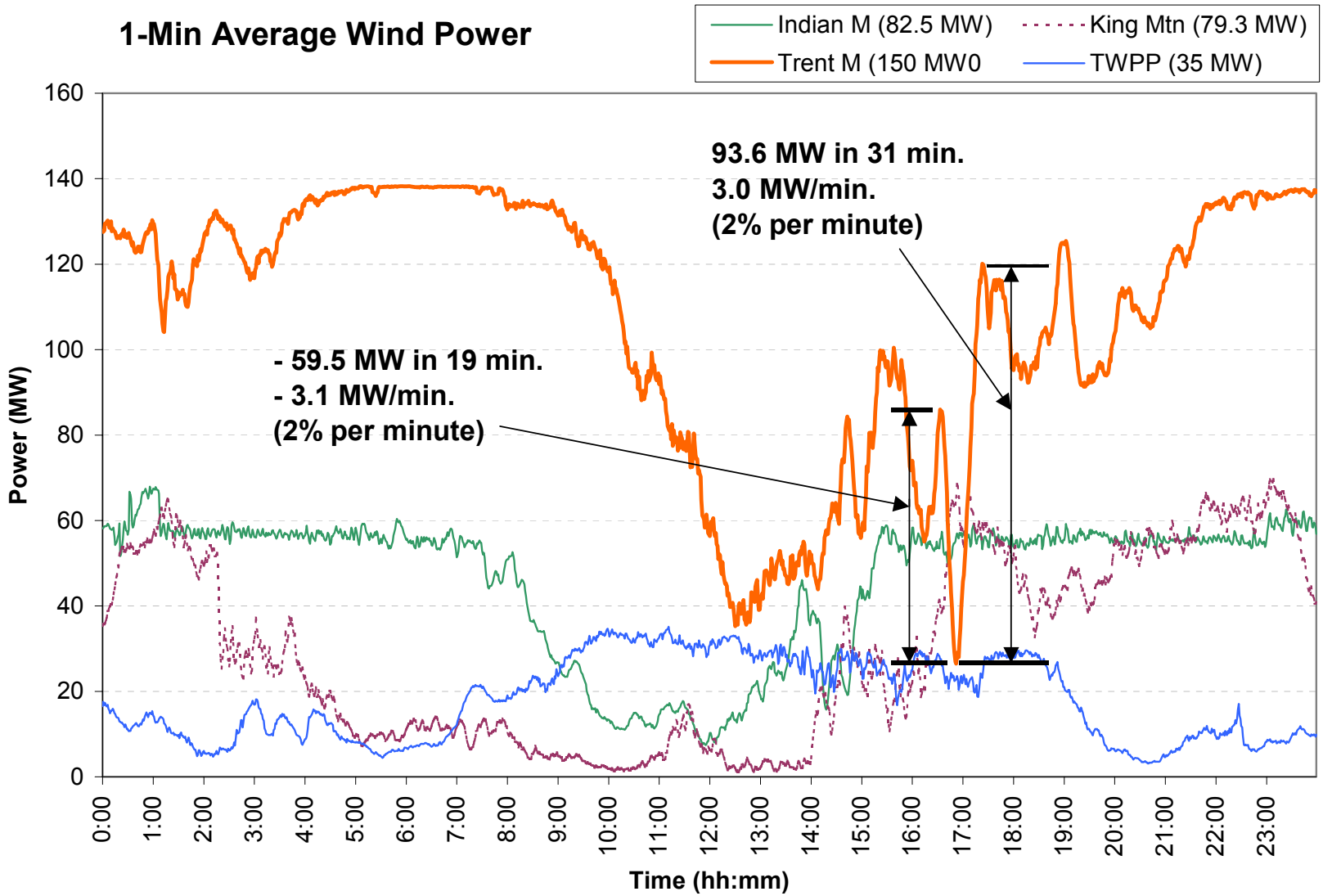
Colberson County, TX
TWPP
Kenetech 330/35 MW
2003

Upton County, TX
King Mountain
Bonus 1.3MW/79 MW
2003

Pecos County, TX
Indian Mesa
Vestas V47/83 MW
2003

Taylor County, TX
Trent Mesa
GE 1.5MW/150 MW
2003

# Example Wind Farm Power Data



# Wind Power Ramping

**Average Wind Power Ramping:** 0.5 MW/min or 0.5%/min

## Example European Grid Code ramping limits:

- 30 MW/min or 100 MW/10 min
- 5% rated/min

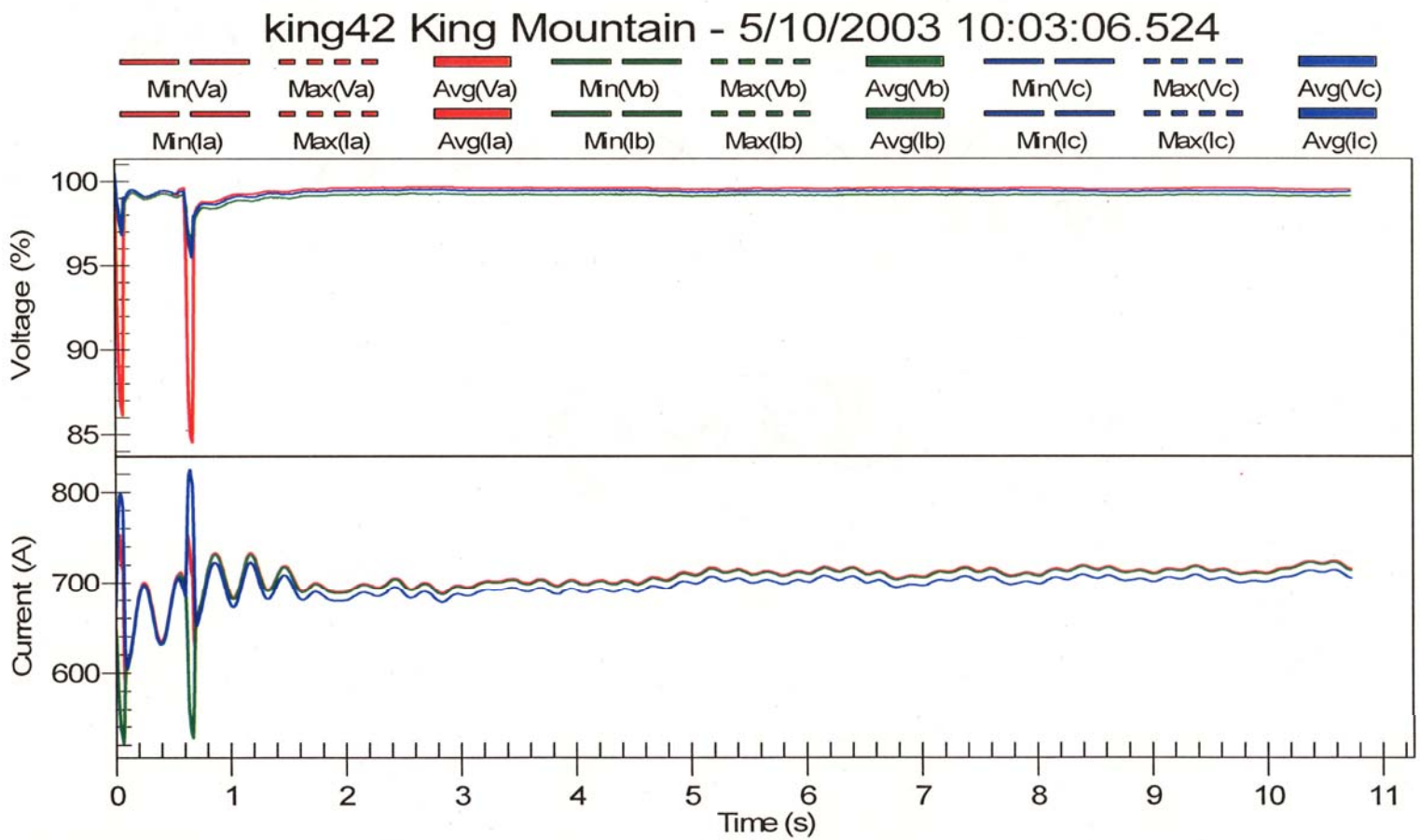
## Typical power plant ramping capabilities:

- Hydro 50%~100%  per minute
- Combustion turbine 10%~20% per minute
- Coal plant 3%~5% per minute

## Load changes:

Standard deviation of 10-min load changes 60 MW (9 GW system)

# Example Disturbance Data



# What We Have Learned

- Short-term fluctuations are confined in narrow range;
- Step changes and ramping rates are more influenced by the size of the plant (number of turbines); they appear to be independent of plant locations and turbine types
- Ramping caused by wind speed changes are seldom severe
- Temporal and spatial diversity of wind speed reduce the variability of wind power
- Simple scaling of output from small wind power plant to match output of large wind project exaggerate fluctuation and ramping behavior
- Availability of utility system information continues to be an issue in the system impact studies

# What Are Still Needed

- Collect and develop a high-frequency database (wind farm output and system conditions) for wind farm dynamic model validation
- Collaborate with utility stakeholders to assemble synchronized system data (load, generation, interchange, and ACE) to assess the wind power impact on system operations

# On Going Efforts for FY2005

- Capture transient event data for wind farm model validation
  - Develop high speed data acquisition system
  - Work with PacifiCorp to collect Wyoming Wind Energy Center turbine and plant responses under fault conditions (NREL will monitor 3 turbines inside the plant, PacifiCorp will monitor the plant at the interconnection point)
- Work with utility partners to collect system data along with wind power data for system impact analysis
  - Work with Western Farmers Electric Cooperative in Oklahoma to save system load, frequency, ACE, interchange, and generation data along with Blue Canyon Wind Power plant output
- Continue the effort to add wind power plants in different regions to the monitoring program for better characterization of wind power spatial diversity

# On Going Efforts for FY2005
**(continued)**

- Wind power primer for utility planning engineers
- Use AREVA T&D system simulation software (DTS) and work with utility partners to analyze wind power ancillary service requirement (possible partner SMUD)

# Industry Collaborations

- System Impact study
  - Xcel Energy northern system could include 1,500 MW of wind power by 2010 (currently 470 MW)
  - Wind impact study required by Minnesota Legislature; Minnesota Department of Commerce responsible for the study; EnerNex performed the work; 1-second Lake Benton data were used
  - Report available at http://www.state.mn.us/mn/externalDocs/Commerce/Wind_Integration_Study_092804022437_WindIntegrationStudyFinal.pdf
  - Generation reliability impact: average capacity value 25.9% of nameplate (388 MW out of 1,500 MW)
  - Integration costs: additional regulation duty $4.37/MWh
  - Load following effect: standard deviation of hourly deviation increases from 53.4 MW to 64 MW with 1500 MW of wind capacity

# Industry Collaborations
**(other studies)**

- EPRI/DOE Energy Storage Handbook (Technology Insights)
- Wind power impacts on electric power system operating costs (NREL, Milligan)
- WAPA rate study (WAPA/ORNL/NREL)
- S&C Electric Company (Energy storage device for wind)
- UT Austin
- Wind energy market value study (Energy and Environment Research)
- Wind Power Plant Behaviors: Analyses of Long-Term Wind Power Data
  http://www.nrel.gov/docs/fy04osti/36551.pdf